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A survey of China's low-carbon application practice—Opportunity goes with challenge

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ABSTRACT

The steady and maintainable energy supply for human development provides the strong motivation, which is necessary to every country in the whole world. The high strength carbon emissions has brought great harm to the earth since industrialization before hundreds of years, and the global warming and extreme weather cause humans to develop low-carbon economy. Low-carbon economy has become a consensus of the entire human race no matter developed countries or developing countries, which is the combination of the lifestyle changing and production structure basic changing and technical innovation. It is well known that China is the largest developing country in the world. With the rapid industrialization of country, energy demand of Chinese society is increasing in an incredible speed, China has become the second largest energy consumer and the first carbon emissions country at present. Furthermore, Chinese energy structure and production methods are very inappropriate, which cannot guarantee the sustainable development of China in future, and therefore actively developing low-carbon economy is the only road to realize China's economic development mode change and sustainable development, which is supported by central government and local governments. Low carbon economy for China is not only an opportunity but also a great challenge. Firstly, this paper discusses the current situation of energy supply and energy structure in China. Secondly, current situation of units' energy consumption in China is discussed. Thirdly, some application practices of low carbon are described, such as low carbon traffic, low carbon city, and low carbon village. Then, the policies and law of China central government and local governments are described in the following paragraphs. At the end, the developmental prospect of low carbon economy in future China and the development barriers and recommendations are introduced, respectively.

Contents

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1. Introduction

With biomass energy, fossil foul resources and nuclear power development and application, the whole human society gradually develops from the primitive civilization to agricultural civilization and modem industrial civilization. But with the global population and economic scale continuous growth, energy in global development provides a powerful driving force, but also brings a series of environmental problems, such as greenhouse gas emissions, environment pollution and acid rain. Especially, industrialization since hundreds of years ago, the concentration of greenhouse gases in the atmosphere grows rapidly, which brings rapid rise of global temperatures, and more and more extreme weather has become an indisputable fact.

For an example, carbon dioxide (CO_2) is the most important greenhouse gas in the global atmosphere. For about 10,000 years before the industrial revolution, the atmospheric concentration of CO_2 was nearly constant about 280 ppm, which represented a balance among the atmosphere, the oceans and the biosphere, which has increased by 38% from 1750, up 1.6 ppm from 2008. The mean growth rate has been 1.88 ppm over the past 10 years. Methane (CH_4) was about 700 ppb before the industrial revolution. The concentration of CH_4 in the atmospheric has increased by 158% from 1750. Globally averaged CH_4 in 2009 was 1803 ppb as compared with 1798 ppb in 2008, up 5 ppm from the years before, and the mean growth rate has been 2.2 ppb over the past 10 years. The atmospheric abundance of nitrous oxide (N_2O) prior to industrialization was 270 ppb. Globally averaged N_2O during 2009 was 322.5 ppb, up 0.6 ppb from 2008 and 19% above 1750. The mean growth rate has been 0.77 ppb per year over the past 10 years, here, ppm is the number of molecules of the gas per million molecules of dry air, and ppb is the number of molecules of the gas per billion molecules of dry air. The rising concentration of greenhouse gas in atmospheric induces that the temperature of earth is constantly rising in the past decades [1].

According to the statistics data of the World Meteorological Organization (WMO), the year 2010 is almost certain to rank in the top three warmest years since 1850, and 2001–2010 is the warmest 10-year period on instrumental climate records. Over the 10 years from 2001 to 2010, global temperatures have averaged 0.43 °C above the 1961–1990 average, the highest value yet recorded for a 10-year period. Fig. 1 shows that the global average temperature anomaly (°C) over the 161 years from 1850 to 2010 [2]. The global temperature anomaly has induced the more and more extreme weather in the world, i.e. super hurricane, drought, floods, sea-level rise. Global temperature induces glacier melting located in the Arctic and Antarctica and High Mountain, and melting snow cause currents change and rising sea levels, while rising temperatures caused the greenhouse gas emissions of permafrost under.

So the traditional growth pattern in the 20th century must be rejected and low-carbon economy mode and low-carbon lifestyle in 21st century for world countries are very important, it is possible to realize the sustainable development of the world. The concept of low carbon economy is presented in the British energy white paper “our energy future: create a low-carbon economy” in 2003 [3]. The goal of low carbon economy is based on reducing greenhouse gas emissions and constructing a low energy consumption and low pollution economic development system, including low carbon energy system, low carbon technology and low carbon industry system. Low carbon economy and low carbon energy systems refer through developing clean energy sources, such as wind, solar, nuclear energy, geothermal and biomass energy alternatives such as coal, petroleum and other fossil energy to reduce carbon emissions. Low carbon technologies include clean-coal technology and carbon dioxide capture and storage technology. Low carbon industry system includes thermal emission reduction, new energy vehicles and energy-saving building energy conservation and emission reduction, and industrial circular economy, resource recovery and environmental protection equipment, energy-saving materials, etc. [4].

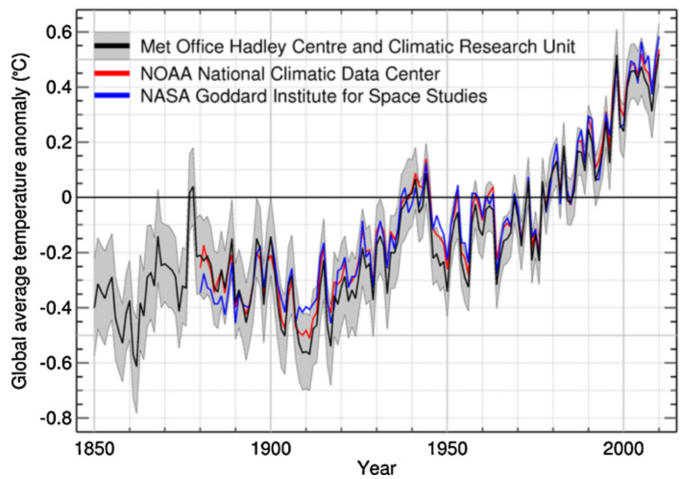


Fig. 1. Global average temperature anomaly from 1850 to 2010. Ref. [2].

It is well known that China is the largest developing country in the whole world. With the rapid development of industrialization, the total energy demand is high. The total installed capacity of electric power is about 0.86 billion kW in 2009, and the share of thermal power generating capacity accounted for about 75.8%. The total energy wastage of coal is more than 2.74 billion tons in 2008, which ranks the first in the world. And the wastage of oil is about 0.36 billion tons, which ranks the second in the world. And wastage of natural gas is about 80.7 billion m^3 [5]. The total amount of CO_2 emission is about 6 billion tons, which ranks the first in the world and the total emission is nearly equal to USA [6,7]. The total amount of SO_2 emission from 2000 is more than 20 million tons, which ranks the first in the world [8]. The inappropriate energy structure will block the sustainable development of country in future. At the same time, the zoology is seriously polluted due to the large scale exploitation and transportation and application of the fossil fuel resource [9,10]. Furthermore, the energy consumption per unit of gross domestic product (GDP) in China is higher than that in the other major nations. The energy consumption per unit in China is about three times than that in US and four times than that in Japan [11,12]. The high strength carbon emission is inevitably due to the very low energy efficiency. Certainly, the sustainable development of country is impossible. Fortunately, Chinese central government and local governments have realized the importance of low carbon economy, and some incentive policies have been for-

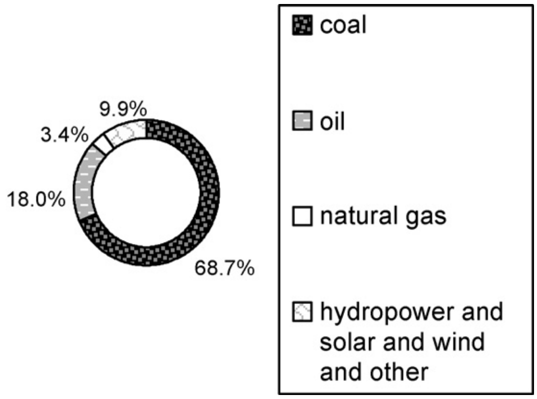


Fig. 2. China's energy structure in 2009. Refs. [13–15].

mulated in order to achieve the sustainable development in future, such as low carbon building, wind generating system, solar energy heating water, and photovoltaic (PV) generating system. More and more companies and capital have been added to low carbon economy, and of course the development process is also facing many questions, but China's low carbon economy will have a brighter tomorrow.

This article will discuss the current situation and outlook of low carbon economy in China. Firstly, the current energy situation is described. Then, the current situation and application practice of low carbon are described in the following section. The following section introduces the policies and barriers. Finally, the prospect of low carbon economy in China is forecasted in this paper.

2. Current energy situation in China

The GDP of China in 2010 will rank the second in the world, and just behind USA, approximately one-third of the United States. At the same time, the total energy wastage ranks the second in the world. According to statistical data, the coal wastage is more than 2.74 billion tons in 2008, which ranks the first in the world, and the oil wastage in 2008 is about 0.36 billion tons, which ranks the second in the world. And natural gas wastage in 2008 is about 80.7 billion m^3 [5]. The total energy consumption in 2009 was 3 billion tons standard coal [13]. Fig. 2 shows a graphical representation of Chinese energy structure in 2009. Chinese energy supply is highly dependent on primary resources, such as coal, oil, and natural gas. Coal energy has a share of 68.7% in 2009, which is the most important fossil fuel in China. Renewable energy and nuclear energy has a share of 9.9%. Oil energy has a share of 18% and the remaining 3.4% is supplied by natural gas. The graphical representation of Chinese energy structure in the past 10 years can be seen in Fig. 3. Statistical data of Chinese energy structure in the past 10 years are shown in Table 1. As shown in Fig. 3 and Table 1, as China's most important coal energy, their status in the past 10 years almost did not make any change, and the main change is that the share of renewable energy and nuclear energy in the whole energy structure was 9.9%, up 3.2% from 2000 [13–15]. The energy structure is very inappropriate to sustainable development and the unlimited use of coal has given China serious environmental problems such as water pollution, greenhouse gas emissions and acid rain, especially in the primary energy will be rapid depletion situation, sustainable low-carbon economy is China's future inevitable development way.

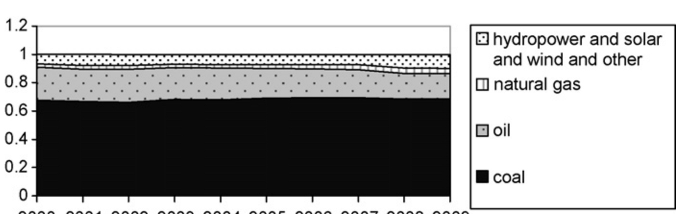


Fig. 3. China's energy structure in the past 10 years. Refs. [13–15]. Note: 2010 China statistical abstract.

3. Current situation of units' energy consumption in China

The influence of the global warming urgent situation, with low energy consumption and low pollution on the basis of "low carbon economy" has become global hotspots. Developed countries vigorously promote energy efficiency and low carbon emission is the core of the low carbon revolution, focus on the development of low carbon technologies, and to industry, energy, technology, trade and other policy reformed in, so as to capture part initiate and industrial commanding heights. Low carbon economy duel in the global has already quietly began. This is the pressure on China, but also a challenge [16].

Low carbon economy can guarantee the sustainable development of economic condition or effect on the effect-quantity condition, reduce energy consumption per unit of GDP, and reduce overall energy consumption. In low carbon economic mode, from consumer begin, commerce and manufacturing business must reduce energy consumption by using a variety of energy-saving products to improve efficiency and ensure steady sustainable development. China has abundant coal resources, according to statistics, the total exploitation amount of coal in China is more than 200 billion tons, so China has not thought that energy can really affect China's economic foundation in the past decades, instead, most of the local government leaderships' hasty thought of energy saving and emission reduction would influence economic development, who is not willing to take the first step in energy conservation and emission reduction. Facing the present situation of energy prices soaring, if also not value low carbon economy development, they will meet with the evil consequences of high carbon economic in the foreseeable future [17].

For an actual example, the energy consumption per unit of GDP of the major nation in the world can be seen in Table 2. The energy consumption per 100 million dollars was 46.3 thousand tons, down 34.8 thousand tons from 2000. But the energy consumption per unit is several times that of developed countries' energy consumption per unit, such as US, Japan, UK, and Italy, even, than India's unit energy consumption. In a word, China has a huge energy pressure, if China do not change the current energy structure and development way, national industrialization and the way of sustainable development are impossible, so low carbon economy, the large-scale exploitation and application of renewable energy are China's future development direction. Low carbon economy has a far-reaching implications for China, it is not only the country's energy security problems, but also the future of China [11,12].

4. Low carbon applications in China

President Hu Jintao in 2009 September in the UN climate summit put forward China's government to reduce carbon emissions, the development of low carbon economy determination. Global climate change deeply affects human survival and development and is the common of the facing challenges. Climate change is an important issue which affects the human development. It was not only affected by natural factors and human activities, but also affected by the influence of environmental factors. Other countries in developing stage, life style, population, resource endowment and international industrial division are also related closely. In the final analysis, the climate change should be able to promote the develop-

Table 1
Statistical data of Chinese energy structure in the past 10 years.

Items	Years									
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Coal	67.8%	66.7%	66.3%	68.4%	68%	69.1%	69.4%	69.5%	68.7%	68.7%
Oil	23.2%	22.9%	23.4%	22.2%	22.3%	21%	20.4%	19.7%	18%	18%
Natural gas	2.4%	2.6%	3%	2.6%	2.6%	2.8%	3%	3.5%	3.8%	3.4%
Other	6.7%	7.9%	7.7%	6.8%	7.1%	7.1%	7.2%	7.3%	9.5%	9.9%

Refs. [13–15].
Note: 2010 China statistical abstract.

ment process, should be able to only rely on common development to solve. China attaches great importance to and actively promotes humanist, comprehensive, coordinated and sustainable scientific development, put forwards that the construction of ecological civilization is an important strategic task, stresses the need to insist on resource conservation and environmental protection of basic state policies, and adheres to the road of sustainable development, accelerates in building a resource-conserving, environment-friendly society and building the innovative country in the process of continuously contributing to combat climate change. [18]. Premier Wen Jiabao of the state council in November's standing committee of state council decision proposed in 2020 Chinese unit of GDP carbon emissions than 2005 reduce 40–45%, meeting decided by 2020, the gross domestic product in carbon dioxide emissions as binding index into the national economic and social development of long-term planning, and to formulate relevant domestic statistics, monitoring and assessment method. Conference also decided that by devoting major efforts to developing renewable energy by 2020, China the fossil energy accounted for an energy consumption of proportion reached approximately 15%. Through forestations and enhanced forest management, forest area more than 2005 increase 40 million ha, forest volume increased more than 2005 1.3 billion m^3 [19]. The stimulus laws have been established by the central government and local governments, low-carbon economy in China is rapid development. For example, many Chinese cities have appeared many low carbon activities, such as low carbon traffic system, free rent bicycle, urban greening and low carbon building. In the vast rural areas appeared millions of methane tanks, and the faecal of people and livestock is fermented to produce the cleaning and pollution-free methane, which are used to afford enough clear fuel for the ordinary farmers, and benefiting farmer's number is over 30 million. Millions of hectare farmland is converted into forest in order to decrease the soil erosion. And besides some renewable energy projects in China, they had been applied to realize the sustainable development, such as photovoltaic or wind power generation lighting system, water pump and grid generating system.

4.1. *Low carbon traffic*

According to the data of ministry participated until 2010 October, Chinese motor vehicle quantities will break through the 200 million cars, including automotive 85 million vehicles, by 2010 China automobile sales will be of 17 million vehicles. Along with the urbanization level increase, the rising amount of motor vehicle in domestic cities is fast, such as Beijing have more than 400 million cars, and each cycle of one million vehicles increased obviously reduced. As mentioned above, the future of China's energy security and the environment will be more prominent. The energy conservation and emission reduction of traditional auto and new energy vehicles industrialization have made China's automobile industry solve major issue. At the same time, the increasing private cars and taxis make carbon emissions more serious, therefore reinforce low carbon traffic construction has become the urgent problems. Fortunately, the Chinese government has been aware of the problem, rail transportation, public transportation, and renewable energy car such measures have been taken to implement them [20].

At present, the rail transportations have been established in some Chinese big cities, such as Beijing, Shanghai, Guangzhou, and Shenzhen. For an actual example, Shanghai has already owned general 424 km, total of 11 line of the subway, in 2010 September 21, metro traffic volume was to reach 6960 thousand person-time, refresh one-day highest passenger [21]. At the same time, many medium-sized cities in China began to build rail transit, and increased public traffic density in order to increase the ordinary people to take public transportation subsidies, such as in Taiyuan, Shanxi Province, 2009 bus fare from 0.15 to 0.5 dollar per person-time, but by 2010, all the bus fares unified to 0.08 dollar per person-time, also in plan of rail transit. At present, China

Table 2
The world's major national energy consumption per unit of GDP (unit: 10,000 tons oil equivalent per 100 million dollars).

Country	Years								
	2000	2001	2002	2003	2004	2005	2006	2007	2008
US	2.35	2.22	2.18	2.09	2.00	1.88	1.76	1.71	1.62
Japan	1.10	1.25	1.30	1.20	1.13	1.15	1.18	1.17	1.03
UK	1.55	1.57	1.40	1.23	1.05	1.01	0.94	0.78	0.80
Germany	1.73	1.77	1.63	1.36	1.20	1.16	1.13	0.94	0.85
France	1.91	1.92	1.75	1.44	1.27	1.22	1.15	0.99	0.90
Italy	1.59	1.57	1.43	1.19	1.06	1.04	0.98	0.85	0.77
Canada	4.15	4.15	4.10	3.59	3.16	2.85	2.52	2.30	2.36
Australia	2.66	2.86	2.66	2.07	1.76	1.60	1.61	1.34	1.17
Russia	24.07	20.25	18.39	14.83	10.94	8.41	6.86	5.29	4.26
China	8.11	7.60	7.28	7.46	7.38	7.04	6.42	5.67	4.63
India	6.29	6.13	6.11	5.19	4.99	4.48	4.19	3.60	3.56
Brazil	3.04	3.53	3.96	3.63	3.13	2.43	1.87	1.64	1.41

Refs. [11,12].
Note: BP Annual Review 2009.

has appeared more successful electric automobile enterprises, such as Build Your Dream (BYD), it to develop hybrid primarily. In a word, the low carbon traffic has been regarded by the central government and local governments and ordinary people at present, and the low carbon traffic in China will have a beautiful future.

4.1.1. Electric vehicle

Green energy-saving traffic in China is experiencing a high growth stage, become ecological energy-saving is an important part of urban construction. At present, many domestic cities have established bus rapid transit. The subway is now declining at 30 billion dollars investment growth, plus the subway adopts the new type of linear motor technology, make the whole cost reduced a quarter. Meanwhile, electric bicycle quantity has also increased. China electric bicycle has reached 1.2 million cars, and expanding at an annual rate of 30%. From the perspective of energy consumption, electric bicycle is only one-eighth of motorcycles and twentieth of cars. From occupancy space look, an electronic bicycle occupies space of only twentieth of cars, which is very effective energy saving transportation [22].

In 2010, China's automobile industry development BBS, Chinese science and technology minister, Wangang points out, after 10 years of efforts, China in electric automobile technology, battery, motor, control system, technical standard and detection capabilities, basic research and international cooperation got rapid progress, the next step is the key job application promotion and marketing. According to experts prediction it is expected to end in China by 2010, new energy vehicle quantities will reach 10,000 vehicles level, by 2017, will reach million cars and even 9 million vehicles, by 2020, China's electric car will likely to retain 10 million level, family car market will make up to 20% of the scale [23,24].

4.1.2. Revival of the bicycle

China is called the kingdom of bicycles, the nation's bicycle quantity is about hundreds of million. But along with the rapid development of China's economy, this accords with low carbon life means of transportation from the people's life which is disappearing gradually, the main reason was that more and more people have enough economic ability to buy cars. China produced 76.06 million bicycles in 2009, down 13.2 percent from 2008, which was the largest decrease since 1996, while the country produced 23.69 million electric bicycles in 2009, up by 8.2 percent compared with 2008, said Ma Zhongchao, chairman of China Bicycle Association (CBA), at the recent 10th China Northern International Bicycle Exposition in Tianjin. Production of traditional bikes declined while production of electric bikes continued rising last year in China. [25].

If the government encourages low-carbon economy situation, the revival of the bicycle gets some insight attention, they think that ordinary people in more recent travel distance of cases, still like using bicycle, the key problem is bike deposit, and inability to free use bicycles. In this case, some local governments have begun providing free bicycle rental services, and increase the storage location for bicycle to raise people using bicycle frequency, reduce carbon dioxide emissions. For example, Minhang district of Shanghai government in some university launched a free bicycle rental services, people can borrow the car in 4 h free use of bicycles and do not need to pay any expenses, and this movement greatly improves the local bicycle use frequency. In a word, the revival of the bicycle in China is not a bosh, which needs the support of ordinary people and government.

4.2. Low carbon city

There are more than 1000 cities in China, and the city's population is more than 100,000. China has more than five super big cities, such as Shanghai, Beijing, Guangzhou, Chongqin and Tianjin. The population of each super big city is more than 10 million. Certainly, the energy wastage amount and the greenhouse emissions are very big, so it is important to decrease carbon emissions. Of course, the Chinese government has already realized the importance of low carbon city to realize the country sustainable development, and to strengthen the publicity of ordinary people, low carbon buildings, application of renewable energy and urban greening is stepping up implementation in the government's support.

4.2.1. Low carbon building

China's urban and rural housing area is more than 40 billion m^2 at present. According to the national bureau of statistics data in 2006, per capita building construction area in city is about to 27.1 m^2, and the city has a population of about 0.577 billion people, and the total construction area of about 15.637 billion m^2. Per capita residential building area in rural is about 30.65 m^2, and then the rural population is approximately 0.737 billion rural residence, it was a total construction area of about 22.6 billion m^2 [26]. Statistical data show China energy-saving building area as only 0.23 billion m^2 till the end of 2002. And according to the analysis, China is at a construction climax period, and built housing area annually of more than 1.6 billion m^2, which is more than all building area in developed countries. Total construction area of more than 97% is energy-intensive architecture. With such construction growth, and that in 2020, the national energy-intensive building area will reach 70 billion m^2. Construction ministry officials pointed out that only to the end of 2000, annual energy consumption goods of Chinese construction are about 0.376 billion tons standard coal, accounting for 27.6% of the whole society terminal of the total amount of energy consumption, and the emissions of greenhouse gases of construction have reached by 25%. Because the energy-intensive architectural proportion is so large the annual more consumption standard coal of heating area in northern is more than 18 million tons standard coal, and the direct economic loss is about 0.1 billion dollars, and the more emissions of carbon dioxide is about 52 million tons. If dependency on this condition continues to develop, by 2020, Chinese building energy consumption will reach 108.9 billion tons standard coal. Qiu Baoxing, vice minister of Construction Ministry, pointed out that currently unit energy consumption in building field is 2-3 times above as compare to the developed countries, the development of energy saving and green building is urgently needed [27,28].

Of course the Chinese government has realized the important of energy consumption of architecture, low carbon architectural concept has known by the ordinary people. Although at present, China's low carbon building is little, but a batch of photovoltaic architecture, hybrid solar-wind architecture and utilizing geothermal energy building in China have been built.

4.2.2. Green city

By 2008, Beijing city green coverage rate will reach 50%, form urban forest encircles, surrounded greening suburb rural ecological landscape, Beijing will become the world's highest rate of one of the capital cities [29]. The state forestry administration, deputy director of the Zhu LieKe said, 2004, our country city green coverage rate is about 30.2% and per capita public greenbelt area is 6.83 m^2. Therefore, our country will speed up urban forest construction, realizes "city in the woods, road in the green, room in the garden, and the scene" goal. Plans by 2010, make the whole

nation 70% of the city green coverage rate is above 40%, and the per capita public green area reaches 10 m^2 [30]. Urban greening is to plant to improve the urban environment activities. Urban greening ecological environment can improve the city residents living environment quality, increasing CO_2 absorption. Many cities combined road construction, river regulation and the reconstruction of conducting greening work, effectively increased greenbelt area, urban and rural greening integrative construction apace.

4.2.3. Renewable and sustainable energy application in city

The requirement of low carbon economy is to reduce the greenhouse gas emissions, so it is required to use the renewable energy as possible. The renewable resources in China are abundant, such as solar energy, wind energy, and geothermal energy, and which have utilized some domains, such as PV landscape lamp, wind lighting system of city and hybrid solar-wind generating power station.

For some examples, there are hundreds of big cities in China, and the population is more than a million. There are more than 10 million street lamps in those cities. At present, the wind energy and solar energy are utilized in the city road lighting system by some local governments in order to decrease the emissions of greenhouse gas. Furthermore, the PV buildings have been built in some cities, such as Olympic village. Geothermal energy has been used in the heating system of some cities, such as winter heating. The most extensive utilization in city is solar water heater, which is broadly utilized in every community. At present, China has become the biggest solar water heater production, sale and holding country in the world. The accumulative area in 2006 is more than 100 million m^3, and the new incremental area is 20 million m^2 [9,10]. At present, China lighting system in the whole energy consumption of ratio is to 20%, therefore the Chinese government encourages with energy-saving LED lighting to replace conventional lighting lamps and lanterns lighting system, in order to reduce emissions of greenhouse gas es.

But should also see because the city buildings, landscape and the area and so on some factors restriction, city itself in a large-scale develop renewable energy, it is highly unlikely that therefore urban and rural development and utilization of renewable energy should be combined, just may guarantee urban development in future.

4.3. Low carbon village

Rural population in China accounts for 60% of the total number, and the total amount is more than 0.7 billion. China's rural energy structure is mainly in coal, wood and straw, the energy structure is more unreasonable than the city, every year there are a lot of forest destruction, and the soil erosion is very serious [31,32]. The Chinese government has realized the importance of changing rural energy structure, which is not only to protect the environment problem, but also to guarantee the sustainable development of the country's requirements. At the same time China rural has wide area, and natural resources and renewable energy sources are very rich, for low carbon economy and the country's future development, urban and rural areas of renewable energy development and application must be combined.

4.3.1. Green village

China has been a large agricultural nation for thousands of years of farming, which has led China's land to serious soil erosion, especially in the northern and western of China, so the Chinese government has to implement the reforesting policy. Reforestation in western China has come true, which protects and improves the ecological environment, such as the slope located in the soil erosion area and the soil located in the desertification area are stopped in a planned step, and according to local conditions, reforestation, grow grass and restore vegetation. The country executes the reforesting of funds and grain subsidy system, and the state forestry area approved restored, within a certain period of the farmland gratis to provide appropriate subsidies grain, seedling forestation fees and accessorial expenses. The Yellow River basin and northern regions, per year 100 kg of accessorial crude restored, cash 20 Yuan, still zoology forest of at least eight years, also economic forest allowance of five years, grassland subsidies in 2 years. RMB $ restored and waste mountains and land subsidy seedlings forestation of 50 Yuan [33,34]. While the area of the desert in China has more than 1.2 million km^2, every spring winds will form several sandstorms in the northern and western regions, so Chinese government constructed the world's largest plantation protection project in northern and western China, and the purpose is to reduce the harm of sand. The land in China is slowly green which can be clearly seen on the map, forest coverage rate is rising continuously, from the 8.6% in 1948 rise to 16.8% in 1999. By 2008, China's forest area is about 0.195 billion ha and the forest coverage rate will reach 20.36% [35].

The fundamental purpose of these measures is to change the vulnerable ecological environment located in western and northern China and to improve local people's living standard, and large increase in forest area also secured the huge amounts of carbon, reduce greenhouse gas, so green countryside in China has very good prospects for development.

4.3.2. Renewable and sustainable energy application in village

The energy structure in Chinese village is more unreasonable than that in city. In order to achieve the sustainable development and low carbon village, the Chinese central government and local governments encourage the application of renewable resource, such as solar energy, wind energy, geothermal energy and biomass energy.

Some renewable application projects have been established in Chinese village. For some examples, the most extensive utilization in city is solar energy greenhouse, which is broadly utilized in every village, which can improve the earnings of number of farmer and the living of city people because thousands of tons green vegetable is afforded. PV or wind energy water pump is used to banish the desert and improve the irrigation area of northwest farmland. Chinese government has established hundreds of distributed generating system in order to improve the living of remote areas civilians. The ordinary person located in remote areas is difficult to receive the enough fuel. Chinese government encourages the application of methane to reduce the carbon emission. Furthermore, the renewable resource and land are abundant in Chinese village. There are some grid-connect PV or wind generating projects have been established in western and northern China, and the total installed amount is more than 30,000 MW, which can provide a mass of power to city and reduce greenhouse gas emissions.

5. Policies of low carbon economy in China

President Hu Jintao in 2009 September in the UN climate summit put forwards China's government to reduce carbon emissions, the development of low carbon economy determination [18]. Premier Wen Jiabao of the state council in November's standing committee of state council decision proposed in 2020 that Chinese unit of GDP carbon emissions than 2005 reduce 40–45% [19]. Developing the low carbon economy has become China's basic national policy at present. China's low carbon economic development includes several specific strategies. First insist in developing reduction emission, second is active controlling the total population, third is to develop forest carbon capture, fourth is the adjustment of economic structure and implementing measures for energy conservation, and

fifth is to speed up the development of clean energy to reduce unit consumption carbon emissions.

Current resources and environmental pressures already seriously affected the long-term development and sustainable development of China's economy. For many years, China has been the adjustment of economic structure, development mode change and renewable energy development as achieving low carbon economy the important means. There are three most iconic events of China's low carbon: First is in the early 1990s, led by China signed the "Agenda 21 Century", vigorously promote environmental protection, set sustainable development as an important strategy. Second is the entry of the 21 century, with the rise of low-carbon economy, and the Chinese government in 2007 promulgated the national plan to respond to climate change, and in the eleventh five-year plan determined by 2010 emissions reduction targets and policies. Third is 2009 in Copenhagen meeting eve, the Chinese government put forward further in the next decade of the latest commitment to respond to climate change, decided by 2020 the unit of GDP in carbon dioxide emissions than 40% ∼45 percent drop in 2005. The fossil energy accounted for an energy consumption of proportion reached approximately 15%, Forest area increased more than 40 million hectares in 2005, forest volume increased more than 1.3 billion cubic meters in 2005. These actions goal since China accelerates towards low carbon social strategic plan, also marks China's low carbon economic development has entered an interactive cooperation with the international community the new stage [36,37].

For some actual examples, since the 1970s, China has accumulated through family planning, <300 million population born, and equivalent to reducing carbon dioxide emissions by 20%. At present, China artificial forestation preserved area is more than 54 million ha, and the forest reserves volume is more than 1.5 billion m^3. The cumulative amount of carbon dioxide absorbed is more than 5.1 billion tons from 1980 to 2005, which account for about 10% of the China's carbon equivalent of total emissions during the same time. China plans to add 74% of the forest area and 87% of forest volume till 2020, which is expected to increase 3.3 billion tons of carbon dioxide absorbed. In recent 20 years, China's energy utilization efficiency increased a time. Otherwise, now China needs more than double the energy consumption, resources and the environment cannot burden the economic development. Development of clean energy and renewable energy, make low carbon energy structure. The goal is to let the non-fossil energy accounted for a energy consumption of proportion, from the current 10% increase in 2020 by 15%. China has become the world's second largest wind power development superpower, and the total installed amount till 2009 is 25,800 MW, which just behind US [36].

6. Developmental barriers

The current low carbon economic development is supported by Chinese central government and local governments, there are billions of dollars fund has been invested in the low carbon domain. Unfortunately, because of the economic structure and energy structure in current China is very unreasonable, and the core technology and support service system is lacked in low carbon technology field, so the established low-carbon economy development goals have many difficulties and challenges. There are some barriers which obstructed the rapid development of low carbon economy in China, such as policy barrier, financial barrier and technology barrier. [36,37].

(I) *Policy barrier*: The low carbon policy has been established by the central government, but the policies are difficult to be implemented by local governments due to the behalf of local government cannot ensure. For an actual example, Shanxi Province in China is a very important energy province, and the annual coal production is more than 0.5 billion tons, which accounted for approximately 25% of the national coal output. 80% of GDP in Shanxi relates with the coal. If the country promotes low carbon technologies and adjust the energy structure, the coal wastage reduced will directly affect the economic development of Shanxi, so the executed degree of central policy in different province is different.

(II) *Financial barrier*: The development of low carbon economy is in need of abundant fund, which cannot be suffered by the ordinary people and small and medium-size enterprise, so the economic incentives of government is indispensable. For example, the China's housing price is very high as compared with the common people's incomes at present. In certain Chinese cities, each square meter of house prices have already been achieved astonishingly 5000–10,000$, and the Chinese people's per capita income in 2009 is about 3800$, of such high prices of house price cannot be burdened by the common people, if buy low carbon buildings, the unit prices will increase by about 5–∼10%, so although the populace know the benefits of low carbon economy, but also won't buy expensive low carbon buildings. Furthermore, the industrial structure changing of small and medium-size enterprise needs abundant fund, which cannot burden the financial pressure, so the government financial's support is necessary.

(III) *Technology barrier*: The development of renewable energy is one of the key measures to make low carbon energy structure. At present, the share of fossil energy in the total energy consumption in China account for about 90%. The highest carbon emissions coefficient of coal accounts for nearly 70%, even by 2020, still can account for about 60%, so there is need to strengthen the greening of coal production and clean utilization, and vigorously develop renewable energy. The technology of renewable energy application in China is not regarded by government and the experts and university and graduate school at present, and the technical investment is not enough in that it is impossible to exploit the pivotal technology. Some pivotal technologies of renewable energy exploitation are purchased from the developed country.

7. Prospect of low carbon in China

The Chinese government in 2009 decided that by 2020 the unit of GDP in carbon dioxide emissions drop 40–45 percent than in 2005. Although there are many reality difficulties to realize this goal realization, but also exists some favorable factors. First, the low carbon buildings in current China are very little, if large-scale increases the number of low carbon buildings will reduce huge amounts of carbon emissions. Second, the units' energy consumption of China's industrial production is very high, industrial products with high energy consumption and low technology content, if increase technology investment, improve industrial added value, which can reduce huge amounts of carbon emissions. Again, increasing the punishment degree of high energy-consuming enterprise, forced firms to reduce energy consumption, and also can reduce carbon emissions. Increasing renewable energy development and application can also reduce emissions of greenhouse gases. In short, although the current carbon emissions in China is very big, which ranks the first in the world, but with the government, enterprises and ordinary people's attention, China will reduce carbon emissions, and China's economy will benefit from low carbon economy.

8. Conclusion and recommendations

It is well known that China has become the biggest carbon emissions country, this paper presents the current situation and application of low carbon economy in China. With the regard of Chinese government and the hortative policy established, and it can be predicted that the low carbon economy and the production of low carbon service will develop rapidly due to more and more sustainable development pressure in future. Consequently, the central government and local governments have realized the importance of low carbon economy in order to achieve the sustainable development in future. Furthermore, the ordinary people has realized the importance of environment and low carbon living. The low carbon economy in China will have a beautiful prospect in the foreseeable future.

At the same time, China has abundant renewable resources, and the potential of renewable energy application in China is large. Some productions of renewable resources have been utilized in China, such as the hybrid solar-wing lighting system has been used to city road lighting. PV building has been established in hundreds of cities to reduce the carbon emissions. It is predicted that the low carbon has a big potential in future China.

However, although the Chinese central government has regarded the development of low carbon economy, and has established some hortative policies and laws, however, there are some obvious barriers for the low carbon existence, such as policy barrier, economy barrier, technology barrier and market barrier. In order to achieve the sustainable development, the following measures are especially recommended in this regard:

1. The government's strong financial support is necessary to settle these barriers. The applications of low carbon should be promoted by the hortative policy of central government and local governments. The financial support can motivate the enthusiasm of entrepreneurs and increase the low carbon market. The low carbon economy of western and northern remote villages' needs the financial and policy support.
2. Abundant fund should be invested into the research of low carbon technology, and the research in low carbon domain should be encouraged in domestic universities and graduate schools. Furthermore, the international cooperation should be encouraged to improve the domestic technology.
3. The renewable resources exploitation should be accelerated, which include the solar heat, PV generating system, and wind generating system, methane, biomass energy, and geothermal energy and so on. Abundant fund should be invested for the research of renewable energy generating domain. Specially, the large-scale grid-connect generating system by using wind or solar energy should be regarded by central government and local government.

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References

[1] World Meteorological Organization, Greenhouse Gases Reach Record Levels. http://www.wmo.int/pages/mediacentre/press_releases/documents/GHG_bull_6_en.pdf [accessed 26.12.10].
[2] World Meteorological Organization, 2010 in the top three warmest years, 2001–2010 warmest 10-year period. See also: http://www.wmo.int/pages/mediacentre/press_releases/pr_904_en.html [accessed 26.12.10].
[3] UK Energy Paper. Our energy future: creating a low carbon economy. See also: http://www.berr.gov.uk/files/file10719.pdf [accessed 26.12.10].
[4] Baidu. Low carbon economy. See also: http://baike.baidu.com/view/1494637.htm [accessed 26.12.10].
[5] Voice of Germany. The let mount of CO_2 in China ranks the second in the world. See also: http://www.dw-world.de/dw/article/0,2144,1427085,00.html [accessed 18.03.09].
[6] Zhao Y, Wang S, Li X, Wang W, Liu Z, Song S. Development and research bulletin of photovoltaic industry in 2005. See also: http://www.cres.org.cn/person_file/2007-11-30/2007113 0225127.html [accessed 16.03.08].
[7] Martinot E. Global development report of renewable resources in 2006. See also: http://www.cres.org.cn/person_file/2007-11-15/20071115145248.html [accessed 16.03.08].
[8] Chinese Development and Innovation Committee (CDIC). Chinese renewable resources industry report in 2006. See also: http://www.crein.org.cn/view/viewnews.aspx?id=20080410103345304 [accessed 03.06.08].
[9] Liu L-Q, Wang Z-X. The development and application practice of wind-solar energy hybrid generation systems in China. Renewable and Sustainable Energy Reviews 2009;13(6–7):1504–12.
[10] Liu L-Q, Wang Z-X, Zhang H-Q, Xue Y-C. Solar energy development in China—a review. Renewable and Sustainable Energy Reviews 2010;14(1): 301–11.
[11] British Petroleum (BP), BP Statistical Review of World Energy 2009. See also: http://www.bp.com/extendedsectiongenericarticle.do?categoryId=9021605&contentId=7040949 [accessed 26.12.10].
[12] ZhongGuo net and China development net, Wang ZH. The world's emerging industry report: major national energy consumption per unit of GDP compared. See also: http://cn.chinagate.cn/reports/2010-11/12/content_21330887.htm [accessed 26.12.10].
[13] Dongding net. China's energy consumption structure. See also: http://www.docin.com/p-46216536.html; 2009 [accessed 26.12.10].
[14] IN-EN.com. China's energy development report. See also: http://www.in-en.com/finance/html/energy_1610161061586551.html; 2009 [accessed 26.12.10].
[15] The National Bureau of Statistics. China statistical abstract. See also: http://ishare.iask.sina.com.cn/f/10462582.html?all=y; 2010 [accessed 26.12.10].
[16] Scientific papers published nets. Low carbon economy—China's economic development mode change the inevitable choice. See also: http://wenku.baidu.com/view/ec74c123482 fb4daa58d4b2b.html [accessed 26.12.10].
[17] Naland net. Low carbon economy in China is of far-reaching significance. See also: http://www.naland.cn/nalanfuwu/nalanguandian/2010-04-06/143.html [accessed 26.12.10].
[18] Xinhua net. The UN climate change summit held in New York—hu jintao summit opening ceremony and delivered an important speech. See also: http://news.xinhuanet.com/world/2009-09/23/content_12098929.htm [accessed 26.12.10].
[19] Tianjin nets—daily news. Carbon dioxide emissions per unit of GDP by 2020 than in 2005, reduce 40%–45%. See also: http://epaper.tianjinwe.com/mrxb/mrxb/2009-11/27/content_6902515.htm [accessed 26.12.10].
[20] Zhongxin net. China motor vehicle quantities will be broken 2 billion market whether to need to control. See also: http://www.chinanews.com.cn/auto/2010/10-13/2583644.shtml [accessed 26.12.10].
[21] CCTV net. Shanghai metro, passenger more than 5 million. See also: http://news.enorth.com.cn/system/2010/10/11/005172775.shtml [accessed 26.12.10].
[22] XinHuaShe. China electric bicycle quantities reach 1.2 million cars. See also: http://www.csc108.com/newshtml/2010-10-08/6A5339780690E73A1-FF10123FF31EAD0.html?docId=821317 [accessed 26.12.10].
[23] Southern daily. 3–5 years later, Chinese electric vehicle possession or crown global. See also: http://house.focus.cn/news/2010-11-09/1095347.html [accessed 26.12.10].
[24] Netease car. Twelve five-year plan period electric quantities broken million. See also: http://auto.163.com/10/0919/16/6GV5C4UG000816HJ.html [accessed 26.12.10].
[25] CONFUCIUS INSTITUTE ONLINE. China bicycle yields but electric bicycle yield increase. See also: http://www.chinese.cn/adult/article/2010-03/29/content_120357.htm; 2009 [accessed 26.12.10].
[26] Jinan daily. Statistics show that domestic housing total value may exceed 90 trillion. See also: http://news.eastday.com/c/20090916/u1a4662070.html [accessed 26.12.10].
[27] Sina net. Our unit building area energy consumption is the developed country 2–3 times above. See also: http://news.sina.com.cn/o/2005-02-24/10515191582s.shtml [accessed 26.12. 10].
[28] 3158 become rich net. China building energy consumption how serious the problem. See also: http://www.3158.cn/news/20090820/14/075196864_1.shtml [accessed 26.12.10].
[29] Beijing morning paper. Beijing 2008 will be the highest greening rate of the capital of global cities. See also: http://www.lvhua.com/chinese/info/A00000010594-1.html [accessed 26.12.10].
[30] Xinjing News. China's urban afforestation in 2010 will reach 40% and per capita green 10 square meters. See also: http://news.sohu.com/20041019/n222555872.shtml [accessed 26.12.10].

[31] Zhou Z, Wu W, Chen Q, Chen S. Study on sustainable development of rural household energy in northern China. Renewable and Sustainable Energy Reviews 2008;12(8):2227–39.
[32] Zhou Z, Wu W, Wang X, Chen Q, Wang O. Analysis of changes in the structure of rural household energy consumption in northern China: a case study. Renewable and Sustainable Energy Reviews 2009;13(1):187–93.
[33] People net. reforesting regulations. See also: http://www.people.com.cn/GB/huanbao/55/20021225/895611.html [accessed 26.12.10].
[34] Baidu net. Reforesting. See also: http://baike.baidu.com/view/139050.htm [accessed 26.12.10].
[35] Xinhua net. Our country forest coverage rate of 20.36%. See also: http://news.xinhuanet.com/fortune/2009-11/17/content_12476936.htm [accessed 26.12.10].
[36] Wang Chunxin. China's low carbon economic development strategies. See also: http://www.gsstock.com/portal/Info/36646008 [accessed 26.12.10].
[37] 21century economic news. Should balance reduction and economic growth. See also: http://www.naland.cn/ditanyanjiu/hongguanyanjiu/2010-06-24/1073.html.